10/030586
531 Rec'd PCT/PTC 02 JAN 2002
5/PRTS
[10191/2175]

FUEL INJECTOR

Background Information

The present invention is based on a fuel injector according to the species defined in the main claim.

During motorized operation, in the case of direct injection of a fuel into the combustion chamber of an internal combustion engine, particularly with direct injection of gasoline or the injection of diesel fuel, the problem generally occurs that the downstream tip of the injector projecting into the combustion chambers is coked by fuel deposits, that is to say, soot particles formed in the flame front deposit on the valve tip. That is why, for previously known injectors projecting into the combustion chamber, the danger of a negative influencing of the spray parameters (e.g. static flow amount, spray dispersal angle, drop size, skeining ability) exists over their service life, which can lead to disturbances in the running of the internal combustion engine, up to the point of a failure of the injector.

Summary of the Invention

The fuel injector of the present invention having the characterizing features of the Main Claim has the advantage that these aforesaid negative effects of the coking (soot deposit) on the valve tip projecting into the combustion chamber are reduced or eliminated. The application, according to the present invention, of coatings on the downstream valve end, above all, around the outlet areas of the discharge orifices, reduces or prevents the coking or formation of covering (soot) on

the valve end generally negatively influencing the spray parameters and the valve function.

Advantageous further developments and improvements of the fuel injector indicated in the Main Claim are rendered possible by the measures specified in the dependent claims.

It is advantageous to apply layers on the valve end by which either a catalytic conversion (burning) of the deposits is effected, or the surface energy and/or the surface roughness of the component to be coated is reduced, a change in the wetting properties thereby being achieved, or the formation of a reaction layer thereby being prevented.

Brief Description of the Drawing

An exemplary embodiment of the present invention is shown in simplified fashion in the Drawing, and is explained in detail in the following description. Figure 1 shows a fuel injector inserted into a location bore of a cylinder head; Figure 2 shows a fuel injector in a longitudinal section; Figure 3 shows a first exemplary embodiment of a valve end coated according to the invention; Figure 4 shows a second exemplary embodiment of a valve end coated according to the invention; Figure 5 shows an alternative guide and seat area on the valve end at the spray-discharge side; Figure 6 shows a longitudinal section of a fuel injector for auto-ignition internal combustion engines; and Figure 7 shows the end of the fuel injector according to Figure 6 on the combustion chamber side.

Description of the Exemplary Embodiments

Figure 1 shows a cylinder head 1 of an internal combustion engine, particularly a mixture-compressing internal combustion engine with externally supplied ignition, in a cut-off segment. Formed in cylinder head 1 is a graded location bore 2 which extends symmetrically along a longitudinal axis 4 up to a combustion chamber 3. A fuel injector 5 according to the present invention is inserted into location bore 2 of cylinder head 1. Fuel injector 5 is used for the direct injection of fuel, particularly gasoline, but also, for example, diesel, as is shown with reference to Figures 6 and 7, into combustion chamber 3 of the internal combustion engine. Fuel injector 5 is preferably able to be actuated electromagnetically via an electrical connecting cable 6. The fuel is supplied to fuel injector 5 via an intake nipple 7. Fuel injector 5 shown in Figure 1 is a so-called top-feed injector in which the fuel is guided in the axial direction from intake nipple 7 through entire injector 5, it being ejected at end 8 on the spray-discharge side, opposite the end on the intake side, into combustion chamber 3.

To protect fuel injector 5 near to combustion chamber 3 from overheating, injector 5 is at least partially surrounded, for example, with a thermal-protection sleeve 9 likewise inserted in location bore 2, it also being possible to dispense with the thermal-protection sleeve.

Figure 2 shows an exemplary embodiment of a fuel injector 5 according to the present invention in a sectional view. It is an electromagnetically operable valve that has a tubular, largely hollow-cylindrical core 11 which is at least partially surrounded by a magnetic coil 10 and is used as the internal pole of a magnetic circuit. A, for example, graded plastic coil form 13 receives a winding of magnetic coil 10 and, in conjunction with core 11 and a non-magnetic intermediate part 14 partially surrounded

by magnetic coil 1, permits a particularly compact and short design of the injector in the area of magnetic coil 1. Instead of the electromagnetic actuating element, fuel injector 5 may also be actuated in a piezoelectric or magnetostrictive manner.

Provided in core 11 is a traversing longitudinal opening 15 which extends along a longitudinal valve axis that coincides with longitudinal axis 4 of location bore 2. Core 11 of the magnetic circuit also serves as intake nipple 7. Fixedly joined to core 11 above magnetic coil 1 is an outer metallic (e.g. ferritic) housing part 16 which, as external pole or outer conductive element, closes the magnetic circuit and completely surrounds magnetic coil 1, at least in the circumferential direction. Provided in longitudinal opening 15 of core 11 on the intake side is a fuel filter 17 which filters out those fuel components which, because of their size, could cause clogging or damage in the injector.

Joined imperviously and fixedly to upper housing part 16 is a lower tubular housing part 18 which, for example, encloses or receives an axially movable valve part made of an armature 19, as well as a bar-shaped valve needle 20 and an elongated valve-seat support 21, respectively. Both housing parts 16 and 18 are permanently joined to one another by, for example, a circumferential welded seam. The sealing between housing part 18 and valve-seat support 21 is effected, for example, by a sealing ring 22. Valve-seat support 21 has, over its entire axial extension, an inner through hole 24 which runs concentrically with respect to the longitudinal valve axis.

With its lower end, which at the same time also represents the downstream termination of entire fuel injector 5, valve-seat support 21 surrounds a disk-shaped

valve-seat element 26, fitted into through hole 24, having a valve-seat surface 27 tapering frustoconically downstream. Arranged in through hole 24 is valve needle 20 which has a valve-closure section 28 at its downstream end. This, for example, spherical, partially ball-shaped and conically tapering valve-closure section 28 cooperates in known manner with valve-seat surface 27 provided in valve-seat element 26. Downstream of valve-seat surface 27, at least one discharge orifice 32 for the fuel is introduced in valve-seat element 26.

On the one hand, a guide opening 34 provided in valve-seat support 21 at the end facing armature 19, and on the other hand, a disk-shaped guide element 35 arranged upstream of valve-seat element 26 and having a dimensionally accurate guide opening 36, are used for guiding valve needle 20 during its axial movement with armature 19 along the longitudinal valve axis.

The lift of valve needle 20 is predefined by the installed position of valve-seat element 26. One end position of valve needle 20, when magnetic coil 1 is not energized, is established by the contact of valve-closure section 28 on valve-seat surface 27 of valve-seat element 26, while the other end position of valve needle 20, when magnetic coil 1 is energized, is yielded by the contact of armature 19 on the downstream end face of core 11. The surfaces of the components in the last-named stop region are, for example, chromium-plated.

The electrical contacting of magnetic coil 1, and thus its excitation, is effected via contact elements 43 which, outside of coil form 13, are provided with a plastic extrusion coat 44. Plastic extrusion coat 44 may also extend over further components (e.g. housing parts 16 and 18) of fuel injector 5. Leading out of plastic

extrusion coat 44 is electrical connecting cable 6, via which magnetic coil 1 is energized.

The guide and seat area provided in the end of valve-seat support 21 on the spray-discharge side, is formed in its through hole 24 by three axially sequential, disk-shaped, functionally-separate elements. Guide element 35, a swirl element 47 and valve-seat element 26 follow one another in the downstream direction. A compression spring 50 enclosing valve needle 20 secures the three elements 35, 47 and 26 in place in valve-seat support 21. Swirl element 47 may be produced inexpensively, for example, by stamping, wire EDM, laser cutting, etching or other known methods from a sheet metal, or by electrodeposition. An inner swirl chamber and a plurality of swirl ducts opening through into the swirl chamber are provided in swirl element 47. In this way, before valve seat 27, a swirl component is impressed on the fuel to be ejected, so that the flow enters with a swirl into discharge orifice 32, and a fine-swirled and well-atomized spray is delivered into combustion chamber 3.

During motorized operation, in the case of direct injection of a fuel into the combustion chamber of an internal combustion engine, the problem generally occurs that the downstream tip of the injector projecting into the combustion chamber is coked by fuel deposits, that is to say, soot particles formed in the flame front deposit on the valve tip. That is why, for previously known injectors projecting into the combustion chamber, the danger of a negative influencing of the spray parameters (e.g. static flow amount, spray dispersal angle, drop size, skeining ability) exists over their service life, which can lead to disturbances in the running of the internal combustion engine, up to the point of a failure of the injector.

According to the invention, these aforesaid problems are reduced or eliminated by applying coatings at valve end 8. In this context, different effects on surface 54 of the component to be coated, e.g. on valve-seat element 26 made of Cr-steel, are attained by different coatings; ultimately, however, all measures are aimed at reducing or preventing the coking or formation of covering (soot) on valve end 8 which has a generally negative influence on the spray parameters and the valve function. Individual coating possibilities are described in greater detail in the following.

Catalytically acting layers represent a first group of coatings. The electrolytically applied layers provide for a catalytic conversion (burning) of the deposited soot particles or prevent the deposit of carbon particles from the start. Suitable materials for such a coating to avoid coking are cobalt and nickel oxides and oxides of alloys of the metals indicated. The noble metals Ru, Rh, Pd, Os, Ir and Pt, and alloys of these metals among themselves or with other metals, also exhibit catalytic effectiveness. The desired layers are produced, for example, by electrochemical or external-currentless metal deposition. In the case of Ni, Co or their alloys, oxide formation in air or an additional oxidation step (using a wet chemical treatment, plasma) may also be used.

The coatings with which the wetting properties on corresponding surface 54 are changed, form a second large group. Achieved by the coatings in this case is that the surface energy and/or the surface roughness of the critical regions at valve end 8 is/are reduced. The interfacial energy between surface 54 and the fuel is thereby increased, which means the wetting deteriorates. In this way, the fuel drops at the regions coated according to the present invention are able to drip off and are entrained by the surrounding flow at valve end 8.

Permanent wetting of valve end 8 no longer takes place. Presenting themselves as such layers are ceramic coatings, carbon coatings which may be metal-containing or metal-free, or fluorine-containing coatings. The fluorine-containing coatings are, for example, heat-resistant PTFE-similar coatings or, in particular, organic ceramic coatings or so-called Ormocer® coatings made of fluorosilicate (FAS). For example, such fluorine-containing coatings are applied by spraying or dipping. Sapphire coatings are also conceivable.

A third group is formed by the coatings with which a reaction layer can be prevented. Among these are, for example, nitrite layers (TiN, CrN) or oxide layers (tantalum oxide, titanium oxide). Similar to sputtering, for these layers, particles vaporized in a vacuum furnace are deposited on surfaces 54 to be coated.

The regions to be coated at valve end 8 are in particular those which immediately surround the at least one discharge orifice 32 in its outlet area 55. Namely, a deposit of soot particles in discharge orifice 32 and/or at its immediate boundary edge leads in particular to the disadvantageous influencing of the spray parameters (e.g. static flow quantity, spray dispersal angle, drop size, skeining ability) indicated above. Thus, in any case, a coating should be applied at the downstream end (outlet area 55) of each individual discharge orifice 32, regardless of on which component of fuel injector 5 discharge orifices 32 are formed.

Figures 3 and 4 show two exemplary embodiments of valve ends 8, coated according to the present invention, in bottom views which differ in that, in one case, entire downstream component surface 54 of the component having discharge orifice 32, here valve-seat element 26, is

coated (Figure 3), and in the other case, only an annular partial area of downstream component surface 54 is coated around the at least one discharge orifice 32 (Figure 4). The dotted areas are intended to clearly show the coated regions. In Figures 3 and 4, outlet areas 55 of discharge orifices 32 lie in the drawing plane. It should be emphasized that the coatings may also extend slightly into discharge orifice 32.

In the exemplary embodiments shown, in each case valve-seat element 26 is the component of fuel injector 5 which forms downstream end 8 and has discharge orifice 32, so that the coating is to be applied at downstream end face 54 of valve-seat element 26. However, the application of a coating according to the present invention is not limited to a valve-seat element, but rather other valve components which form downstream valve end 5 and thus project into combustion chamber 3 may also have such a coating. For such components arranged downstream of valve seat 27 (see spray-discharge member 67 in Figure 5), as well, at least the regions immediately at discharge orifices 32 should be coated, so that the actual spray-discharge area is protected from coking.

Figure 5 shows an alternative guide and seat region at valve end 8 on the spray-discharge side, in order to elucidate that the assertions with respect to the coating of the present invention are also applicable to valve designs which differ structurally. In this exemplary embodiment, a further disk-shaped spray-discharge member 67 is arranged downstream of valve-seat element 26. In this case, spray-discharge member 67 has discharge orifice 32. Discharge orifice 32 is inclined at an angle with respect to the longitudinal valve axis, and terminates downstream in a convexly curved spray-discharge region 66. Spray-discharge member 67 and valve-seat element 26 are permanently joined to one

another by, for example, a welded seam 68 obtained by laser welding, the welding being carried out in an annular circumferential depression 69. In addition, spray-discharge member 67 is permanently joined to valve-seat support 21 by a welded seam 61. For example, the coating is applied either over entire curved spray-discharge region 66, or directly in a ring shape about outlet area 55 of discharge orifice 32, so that relative to the longitudinal valve axis, an off-center coating exists on a curved surface 54.

Figure 6 shows a longitudinal section through a fuel injector for auto-ignition internal combustion engines, particularly diesel engines, only the part facing the combustion chamber being shown. An enlargement of the end of fuel injector 5 on the combustion chamber side shown in Figure 6 is shown in Figure 7. A component constructed as valve member 72 is braced against a valve-retaining member 73 by a tension nut 75. Formed in valve member 72 is a bore 84 in which piston-shaped valve needle 20 is arranged that is axially movable against a closing force. Bore 84 is implemented as a blind-end bore, the closed end facing combustion chamber 3 forming a valve-seat surface 27 which essentially has a truncated cone shape. Due to a bulge of the end of valve-seat surface 27 on the combustion chamber side, a blind hole 92 is formed in whose wall at least one discharge orifice 90 is configured connecting blind hole 92 to combustion chamber 3.

Valve needle 20 is divided into a section, facing away from combustion chamber 3, which has a larger diameter and is guided in bore 84, and a section having a smaller diameter, between which and the wall of bore 84, a pressure space 86 is formed which is able to be filled with fuel under high pressure via an inlet passage 80 formed in valve-retaining member 73 and valve member 72.

Due to the grading of the outside diameter of valve needle 20, a pressure shoulder 82 is formed on it which is arranged within pressure space 86. The fuel pressure in pressure space 86 produces a force on pressure shoulder 82 whose component operating in the axial direction is directed contrary to the closing force operating on valve needle 20, and thus, given suitable fuel pressure, valve needle 20 is able to move against the closing force.

Formed on valve needle 20 at the end on the combustion chamber side is a valve-sealing surface 88, forming valve-closure section 28, which cooperates with valve-seat surface 27 in such a way that the at least one discharge orifice 90 is sealed against pressure space 86 by the contact of valve-sealing surface 88 on valve-seat surface 27. Due to the opening lift movement directed inwardly away from combustion chamber 3, valve-sealing surface 88 lifts off of valve-seat surface 27 and connects pressure space 86 to discharge orifice 90.

The catalytically active coating is applied, for example, over the entire end face of valve member 72 facing combustion chamber 3. It is also possible to provide only curved outer surface 96 of blind hole wall 93, which borders blind hole 92 and in which the at least one discharge orifice 90 is formed, with a coating. Provision may also be made to continue the coating into discharge orifice 90.